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Original Research

Comparison of radiological measurement values and qualitative examination with clinical findings in lumbar spinal stenosis

Lumbar spinal stenosis imaging

Levent Karakas[1], Berna Dirim Mete[2], Erdal Dilekçi[3], İbrahim Halil Erdem[4]
[1] Department of Radiology, Gaziosmanpaşa Training and Research Hospital, Istanbul
[2] Department of Radiology, Faculty of Medicine, Izmir Democracy University, Izmir
[3] Departmen of Physical Medicine and Rehabilitation, Faculty of Medicine, Maltepe University, Istanbul
[4] Department of Physical Medicine and Rehabilitation, SBÜ Istanbul Başakşehir Çam and Sakura City Hospital, Istanbul, Turkey

Abstract

Aim: The study aims to evaluate the utility of "qualitative" and "quantitative" magnetic resonance imaging (MRI) parameters for the radiological diagnosis of lumbar spinal stenosis (LSS), as well as the relationship between these parameters and clinical findings and how to employ them when staging the disease.

Material and Methods: 75 patients with LSS who were receiving care at the Physical Medicine and Rehabilitation clinic and had lumbar MRI were included in our research. At levels where stenosis was at its worst, MRI parameters were assessed. Assessments were made of the relationships between these characteristics and the clinical symptoms that were used to diagnose and stage Oswestry Score (OS) and LSS findings.

Results: The dural sheath area and the dural sheath anterior-posterior diameter(p:0.02) showed the highest connection. The dural sheath area showed the best rate of correlation amongst staging techniques when MRI area and diameters were compared to qualitative staging (p:0.01). The dural sheath diameter showed the best correlation (p:0.02) with the OS when the measurements were compared with the OS. "Neurogenic claudication distance" (NCD) had statistical correlation with "qualitative staging" used most frequently and practically among imaging parameters (P:0.03), which was much lower than the correlation between NCD with "spinal canal area measurement" on axial sections (P:0.005).

Discussion: Our analysis of LSS revealed that the "OS" and NCD, which are particularly useful as indicators for staging, coincided with distinct measurement parameters. Clinical research revealed that the most important technique for NCD disease staging had the strongest association with radiological parameters of spinal canal area measurements.

Keywords

Lumbar Spinal Stenosis, Qualitative Staging; Spinal Canal, Vertebral Degeneration

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Corresponding Author: Levent Karakas, Department of Radiology, Gaziosmanpaşa Training and Research Hospital, Istanbul, Turkey.
E-mail: leventkarakas83@gmail.com P: +90 507 260 86 70
Corresponding Author ORCID ID: https://orcid.org/0000-0001-5485-9337
Other Authors ORCID ID: Berna Dirim Mete, https://orcid.org/0000-0002-2380-4197 · Erdal Dilekçi, https://orcid.org/0000-0001-7507-2808
İbrahim Halil Erdem, https://orcid.org/0000-0003-1979-3672

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Introduction

"Lumbar spinal stenosis (LSS)", which develops due to degeneration, refers to the condition in which the area and volume of the neural and vascular elements of the lumbar spinal canal within the spinal (vertebral) canal become limited due to degenerative changes in the lumbar vertebral column secondary to spondylosis [1-4]. It is generally believed that compression and intertwining of the nerve roots of the "cauda aquina" is the primary cause of symptoms and signs [5]. Currently, magnetic resonance imaging (MRI) is the most commonly used and optimal imaging modality to evaluate the lumbar spinal canal. Although the "diameters of the spinal bone canal in different planes (axial and sagittal)" and, to a lesser extent, the "axial plane cross-sectional area of the spinal bone canal" or the "axial plane cross-sectional area of the dural sac" are well known and accepted radiological measurement parameters in the literature, there are no standardized "quantitatively absolute diagnostic criteria" or "grading method" used radiologically (especially on MRI) to diagnose LSS and grade stenosis [6]. Ogikudo et al. found that there was a very close relationship (correlation) between the "cross-sectional area of the dural sac in the axial plane" surrounded by the dura mater and the clinical signs and symptoms of the patients [5]. In another study, it was concluded that narrowing of the "cross-sectional area of the dura mater in the axial plane" was not correlated with subjectively graded clinical symptoms [7]. Schizas et al. developed a "qualitative examination method" that evaluates the severity of LSS according to the "morphology of the dural sac" and "clinical symptoms of the patients" [8]. However, this classification method is not widely used in clinical and radiologic practice because it is too time-consuming to evaluate. A new MRI classification system for LSS was proposed by Lee et al. in 2011 [9]. Lee et al. classified LSS into four grades according to the structure of the "dural sac" and "cauda equina" on the basis of "standard spin-echo (SE) T2-weighted axial images" obtained by lumbar MRI and claimed that this new classification system is reliable in diagnosing and determining the severity of LSS. The purpose of our study was to investigate the relationship between the "quantitative MRI parameters" used in the diagnosis of LSS and the "qualitative MRI grading method described by Lee et al." and to determine whether there is a correlation between these parameters and the "main clinical symptoms and findings of the patients".

Material and Methods

Selection of Patients

In our study, 75 patients who underwent lumbar MRI with suspicion and preliminary diagnosis of lumbar spinal stenosis in our hospital (İzmir Atatürk Training and Research Hospital, radiology doctor of medicine dissertation) between March 2010 and January 2012 were examined. Forty-five (60%) of the patients were female and 30 (40%) were male. The ages of our patients ranged from 46 to 79 years with a mean age of 54.3 years. The selection of the patients included in our study was made through the electronic information-management system of the hospital we were in at the time and among the patients who had undergone adequate clinical evaluation and physical examination by the Physical Medicine and Rehabilitation Clinic. For the diagnosis of LSS, diameter and area measurements were obtained from all lumbar disc levels. We conducted our research on patients with LSS due to degeneration and disc herniation. Patients with LSS due to causes other than these etiologies (postoperative, congenital, etc.) were excluded from the study. Other main exclusion criteria were a history of tumor, infection, trauma, cerebrovascular disease or other intracranial pathologies and peripheral neuropathy.

MRI Technique and Evaluation of Images

The study was performed on images obtained with a 1.5 Tesla MRI machine (Philis Integra, 2011). The standard turbo spin-echo (TSE) axial T2 sequence and TSE sagittal T1 and T2 sequences were used for lumbar MRI (Table 1).

Measurement of the areas of the spinal bone canal and dural sac from axial sections was performed using software (through the licensed Angora RIS/PACS in our hospital) by determining the boundaries of the area by drawing the boundaries of the area through the image archiving and transmission system (PACS- Picture Archiving Communication Systems). Qualitative evaluation was performed as observational grading according to the rate of compression of the dural sac and obliteration of the a-p distance of the sac. In this grading proposed by Lee et al; "grade 0; normal", "grade 1; mild stenosis" and cauda equina fibers were not compressed, "grade 2; moderate stenosis", cauda equina fibers were gathered together due to compression, "grade 3; severe stenosis", cauda equina fibers were significantly compressed [9] (Figure 1)

The "dural sac area" was measured from axial sections by marking along the "hypointense borders of the dural sac on T2-weighted axial sections". The "spinal bone canal area" was measured from axial sections by taking the "posterior contour of the disc in the front", "flaval ligament in the back" and "vertebral bone structures on the sides" as boundaries and calculating the resulting area. The "anterior-posterior (a-p) diameter of the bony canal" was obtained from the axial sections by accepting "the posterior contour of the disc in front" and "the contour of the inner-frontal surface of the flaval ligament facing the spinal canal in the back" as boundaries. The "a-p diameter of the dural sac from axial sections" was obtained by measuring "the sagittal plane midline distance between the anterior and posterior hypointense borders of the dural sac from the axial section". The "a-p diameter of the bone canal in the sagittal plane" was calculated by measuring the distance between the "posterior contour of the disc" and the "posterior border of the spinal bone canal" based on "midline measurement from the T2 sagittal image at the level of the disc space." The "anterior-posterior diameter of the dural sac in the sagittal plane" was obtained by measuring the distance between the "anterior-posterior borders of the dural sac in the midline from sagittal T2-weighted slices" (Figure 2 and Figure 3).

Clinical Correlation

Neurologic examination and clinical findings were obtained from electronic records in the hospital automation system similar to radiology. In the clinical data in the automation system; questions were asked to determine the Oswestry Score (OS) to determine the back pain (Table 2). One of the clinical manifestations of LSS is claudication. Neurogenic claudication distance (NCD) is an important clinical parameter in determining the severity of LSS. Our cases were also categorized according to NCD.

Statistical Analysis

Data were analyzed using “SPSS (Statistical Package for the Social Sciences) version 22” software (The statistics of the study were updated with a new version of the program). Standard descriptive statistics were used to evaluate the data. The relationships between the variables were defined and tested with Pearson and Spearman Correlation Coefficient and statistical significance and the “r” value indicates the statistical significance rate. For statistical significance, p<0.05 was accepted.

Ethical Approval

This study was approved by the Ethics Committee of İzmir Atatürk Training and Research Hospital (Date: 2011-12-14, No: 168/3).

Results

Imaging Findings and Measurement Values

MRI images of our patients were evaluated by measuring at L1-

Table 1. MRI sequence imaging parameters

Sequence	TR (ms)	TE (ms)	FOV (cm)	Matrix	Section thickness (mm)	Section gap (mm)
TSE T1 Sagittal	800	12	32	366x512	4	1
TSE T2 Sagittal	5300	120	32	512x252	4	1
TSE T2 Axial	4465	120	16	256x216	4	0,4

(TSE: Turbo Spin Echo, TR: Time to Repetition, Time to Echo, FOV: Field of View)

Table 2. Evaluation of the patients according to the “Oswestry Score” and categorization of the number of cases in each score, as well as a summary of the NCDs of the cases

Oswestry Score	How many patients (%)
1. Between % 0 and % 20- Low back pain does not pose a significant problem in the patient's life	16 (%21,3)
2. Between %20 and %40- Low back pain mildly restricts the patient's daily life	32 (%42,6)
3. Between %40 and %60- Low back pain severely restricts the patient's daily life	22 (%29,3)
4. Between %60% and %80- The patient's daily life is completely restricted due to low back pain	5 (%6,6)
5. Between %80 and %100- Bedridden patient (or symptoms are exaggerated)	0 (%0)

Categorization of stenosis by level and number of patients		
Shortest distance (m)	**Longest distance (m)**	**Average value (m)**
20	500	177,3

m: Meter NCD: Neurogenic claudicatio distance

Table 3. Table showing the qualitative staging and categorization of patients according to the degree of spinal stenosis from axial sections, spinal bone canal a-p diameter measurements from axial sections, dural sac a-p diameter measurements from axial sections, and spinal canal a-p diameter measurements at the disc level from sagittal sections according to the number of patients as shown in Figure 1.

Qualitative staging of spinal stenosis from axial sections		
Stage 1	**Stage 2**	**Stage 3**
12 (%16)	30 (%40)	33 (%44)

Number of patients according to spinal bone canal a-p diameter from axial sections (percentage)	
Diameter between 10-15 mm	**Diameter less than 10 mm**
46 (%61,3)	29 (%38, 6)

Number of patients according to dural sac a-p diameter measurement values from axial sections (percentage)	
Diameter between 9-13 mm	**Diameter less than 9 mm**
39 (%52)	36 (%48)

Number of cases according to dural sac a-p diameter (mm) measurement values from disc level in sagittal sections (percentage)		
< less than 10 mm	**10-14 mm arası**	**>14 mm larger than**
26 (%34,6)	49 (%65,3)	0 (%0)

Categorization of stenosis according to lumbar level and number of patients; number (percentage)					
L1-2	**L2-3**	**L3-4**	**L4-L5**	**L5-S1**	**Multiple levels of stenosis**
3 (%4)	5 (%6,6)	7 (%9,3)	14 (%18,6)	16 (%21,3)	30 (%40)

a-p: Anterio-posterior, L: Lumbal mm: Milimeter

2, L2-3, L3-4, L4-5, L5-S1 levels. On T2-weighted axial slices, the diameters of the dural sac and bony canal, as well as the area of the dural sac and spinal canal were measured (Figures 2 and 3).

Spinal stenosis was staged qualitatively according to the compression of the disc to the dural sac on axial sections (Figure 1). In qualitative staging, 33(44%) of the patients were determined as stage 3, 30(40%) as stage 2, and 12(16%) as stage 1 (Table 3).

Axial T2-weighted slices revealed stenosis at the L1-L2 level only in 3(4%), L2-L3 in 5(6.6%), L3-L4 in 7 (9.3%), L4-L5 in 14 (18.6%) and L5-S1 intervertebral disc levels in 16(21.3%) patients (Tables 3). In 30 (40%) of our patients, stenosis was present at more than one level (Table 2). In the measurements made from sagittal sections, spinal canal a-p diameters were measured in the range of 8-14 mm, 26 (34, 6%) of our patients had a sagittal a-p diameter of less than 10 mm, and 49 (65, 3%) patients had a spinal canal a-p diameter between 10-14 mm (Table 3). In our study, spinal stenosis was most common at the L4-L5 and L5-S1 disc space levels, consistent with the data in the literature. Spinal stenosis is most common at the L4-L5 and L5-S1 disc space levels.

When the OS showing the clinical status of our patients was evaluated in Table 2. The patients were also categorized in terms of NCD; the NCD value ranged between 20 and 500 m with a mean of 177.3 m (Table 2).

It was observed that 65 (86.7%) of our patients had neuropathic pain. Neuropathic pain was not detected in 10 (13.3%) of our patients and all of these patients were at stage 1 in LSS qualitative staging (Table 2).

Correlation of Clinical Findings with Qualitative and Quantitative MRI Findings

When the radiologic measurement parameters from MRI examination for the lumbar spinal canal were compared with each other, the strongest correlation was found between "dural sac area measurement from axial slices" and "dural sac anterior posterior diameter measurement" (r:0.927, p:0.02).

When Lee's qualitative staging parameters were compared with area and diameter measurements, it was found that the staging system was most highly correlated with "dural sac area measurement from axial sections" (r:0.847, p:0.01).

Clinically, NCD is accepted as the most determinative method for staging the disease. The radiologic measurement parameter that correlated best with NCD was found to be "spinal canal area measurement from axial section" (r:0.847, p:0.005).

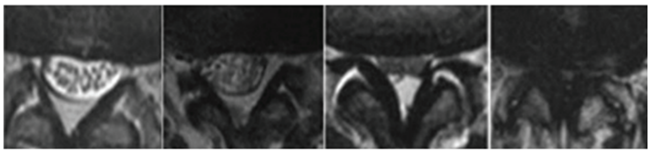

Figure 1. Axial MR image (T2 TSE sequence) roughly representing the status of the cauda equina fibers and dural sac for qualitative staging. Moving from left to right, it is shown how the stenosis is qualitatively graded according to the compression of the dural sac and cauda equina fibers, with the leftmost image representing grade 0 and the rightmost image representing grade 3

Discussion

Lee et al. reported that qualitative stenosis classification based on the anterior compression of the dural sac was very useful in diagnosis and staging. In their study, they also quantitatively evaluated the area and diameter measurement parameters; however, they reported that these values did not provide as much practical benefit as qualitative staging since stenosis cases with different diameter and area values were in the same qualitative stage [9]. Lee et al. did not focus much on the clinical parameters of lumbar stenosis while making this classification.

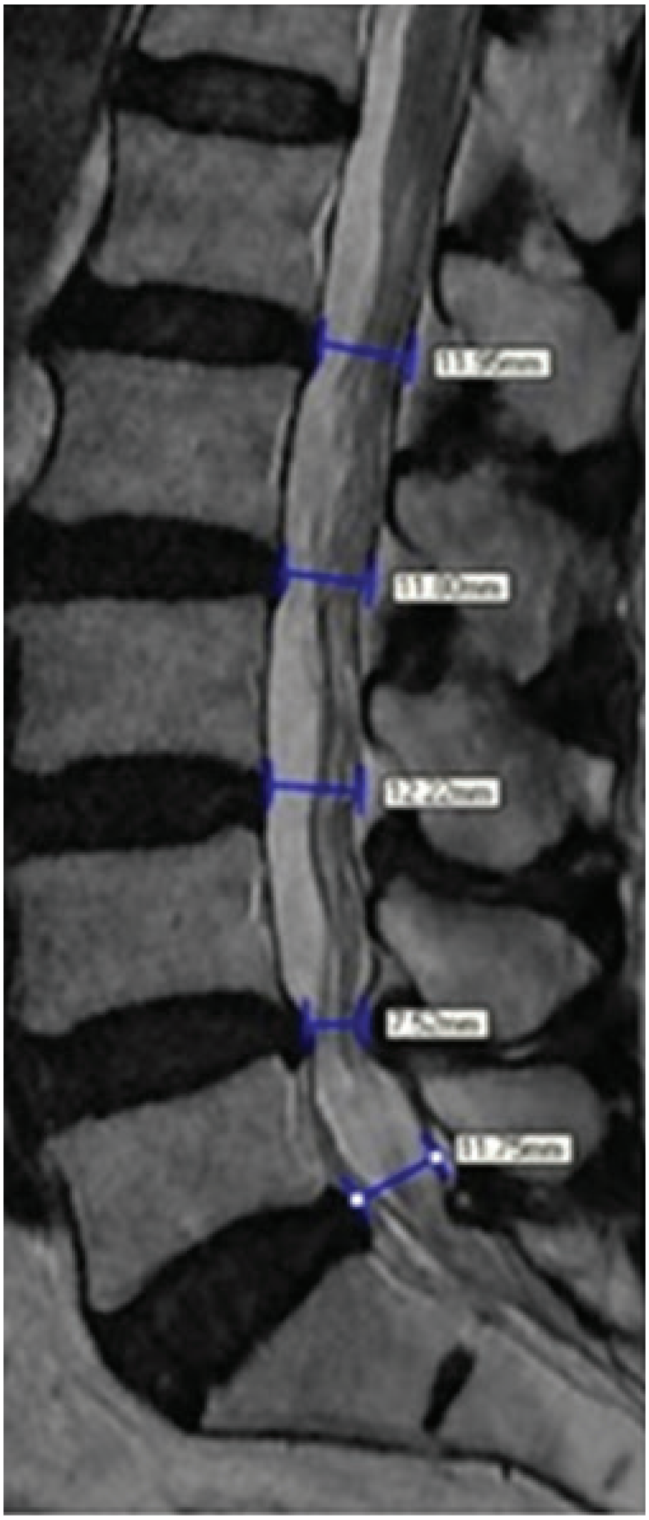

Figure 2. Mid-sagittal T2-weighted lumbar MRI section of one of our patients with a diameter measurement of the dural sac at all disc levels

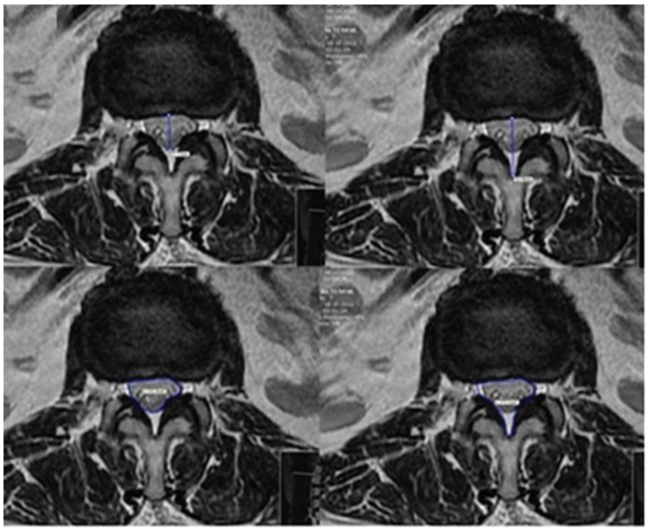

Figure 3. T2-weighted axial lumbar MRI slices of a patient. Measurements were made at the L1-L2 disc level. Dural sac and spinal canal area measurements, dural sac and spinal bone canal a-p diameter measurements (blue line and surrounding areas) were made on each slice

The main starting point of our study is "the idea of the necessity of correlation with clinical data".

Symptomatic spinal stenosis is frequently seen in the middle-aged and elderly population. While LSS is mostly seen in men in early age, it is more common in women than men after the age of 50 [10]. In a study by Andrasinova et al. investigating the radiologic stage of lumbar spinal stenosis and its clinical correlation, the mean age was 67.2 years [11], while in another study by Azimi et al. the mean age was 58.1 years [12]. Although the mean age in our study was lower than the mean age in the study by Andrasinova et al, it was close to that in the study by Azimi et al. This difference may be due to the fact that spinal stenosis due to degenerative processes is seen at a later age in developed countries or the average life expectancy is higher in these countries [12].

In the study by Ergün et al. in terms of spinal stenosis, the female/male ratio was 17/8 (66.3% female, 33.7% male) [13]. This ratio was 88 to 72 (55% female, 45% male) in the study by Park et al [14]. All of these studies were conducted in the age group with degenerative spinal stenosis. In our study, this ratio was 30/45 (40% male, 60% female). Our study has similar results to other literature and supports the literature data that spinal stenosis is more common in women than men after the age of 50 years.

The mean duration of complaints in our patients was found to be 72 months, ranging from 24 to 180 months. Azimi et al. found a mean duration of 40 months with a range of 18 to 60 months [12]. The fact that the mean duration of complaints was found to be high in our study may be due to the fact that in our society, the referral to a physician for spinal stenosis is only in the advanced stages of stenosis.

Kaya et al. found that only the L3-L4 vertebral disc level showed a negative correlation with the spinal canal area among radiologic measurements and the a-p diameter measurement, which is widely accepted in defining spinal stenosis, showed no correlation with somatometric parameters. These findings reveal that walking distance decreases as the canal diameter narrows. In our study, NCD ranged between 20 and 500 m with a mean of 177.3 m. Kaya et al. found the NCD to be between 5 and 650 m with a mean of 300 m in patients with spinal stenosis [15]. This is probably due to the fact that the degree of stenosis in our patients was more advanced compared to the study in the literature.

In our study, spinal stenosis measurement parameters and qualitative staging (according to the degree of pressure on the anterior part of the dural sac) were statistically compared in terms of correlation. In the study by Lee et al., this staging was found to be clinically and radiologically very useful and practical, and it was found that "dural sac area" correlated most with this staging in the comparison of all area and diameter parameters in this staging. The degree of dural sac area measurement from axial sections was found to provide information parallel to qualitative staging. Apart from these, all area and diameter parameters were statistically compared with OS and NCD. It was found that dural sac diameter from axial sections correlated the most with OS.

The most correlated measurement parameter with NCD was sac area. When compared with the correlation analysis of qualitative staging and NCD, the result of this correlation analysis was higher than all other measurement parameters. In other words, it can be said that qualitative staging is the most valuable spinal stenosis evaluation method in terms of NCD. "Spinal canal area measurement from axial sections" was performed and the lowest and highest area values were 58 mm² and 122 mm², respectively. Here, the area value of 10 cases was above the spinal stenosis value. Although the area value is normal for spinal stenosis, sagittal and axial diameter values of these cases are compatible with stenosis. In our study, the reason why spinal canal measurement from axial sections showed the best correlation with NCD, which is the most effective method among the clinical parameters, was thought to be that in spinal stenosis, the canal content other than the dural sac often contributes to the symptoms due to degenerative causes.

When we look at the current studies, there is still no gold standard method for the diagnosis and grading of spinal stenosis, especially in the lumbar region, except for the diameter and area measurement based on MRI examination [8].

Limitation

The limitation of our study is that the area and diameter values did not overlap in every case, albeit slightly. Another limitation of the study is that there were no specific examination findings or clinical information regarding the level of stenosis and the patients were not questioned for motor deficits but only for low back pain and neuropathic pain.

Conclusion

The dural sac diameter measurement from axial sections and the qualitative staging system correlated well with the OS and NCD, and it was concluded that the combination of these methods in diagnosis and grading when planning treatment in lumbar spinal stenosis would be more accurate in terms of clinical evaluation. Furthermore, since dural sac a-p diameter measurements from sagittal and axial slices correlate well with each other, dural sac a-p diameter measurements from sagittal slices instead of axial slices can also be used in the evaluation of lumbar spinal stenosis. In our study, NCD and OS, which are used as clinical indicators for LSS, especially for staging the disease, were found to statistically overlap with different radiologic measurement parameters (diameter and area obtained from MRI). It was found that the radiologic measurement parameter that correlated best with NCD, which is the most decisive method for clinical staging of the disease, was spinal canal area measurement. From this point of view, our study maintains its topicality and scientific value.

Scientific Responsibility Statement
The authors declare that they are responsible for the article's scientific content including study design, data collection, analysis and interpretation, writing, some of the main line, or all of the preparation and scientific review of the contents and approval of the final version of the article.

Animal and Human Rights Statement
All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or compareable ethical standards.

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Conflict of Interest
The authors declare that there is no conflict of interest.

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